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LA RECHERCHE AGRONOMIQUE POUR LE DÉVELOPPEMENT

ECOLE DES MINES D'ALBI
C A R M A U X

Study on gas release during torrefaction of woody biomass and its constituents

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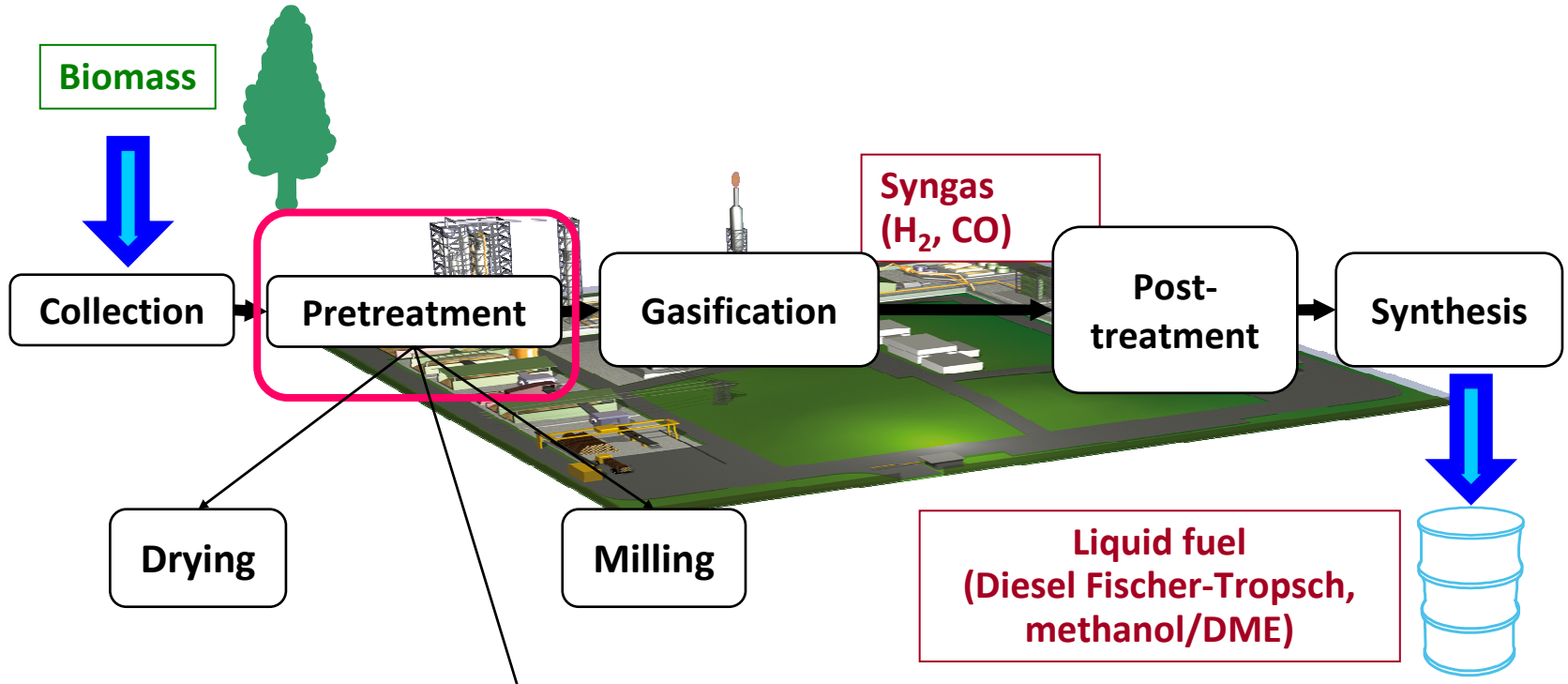
Céline BOACHON, Yannick SOUDAIS, Sylvain SALVADOR

The process: from biomass to fuel



~200 µm "spherical" particles required for injection in entrained flow gasifier

↳Technically difficult and expensive

Thermal pretreatment: torrefaction

- inert atmosphere
- 250- 300°C
- atmospheric pressure

↳Enhances grindability

Torrefaction issues

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	Solid mass loss	Gas and condensables formation
Process	How to keep mass loss as low as possible?	How to deal with harmful gas and condensables?
Fundamental	How does the biomass polymer decompose?	

➡ Torrefaction modelling

Objective and working plan

- **Objective:** To develop a model able to describe kinetics of

Solid mass loss

Gas and condensables formation

- **Approach:** sum of decomposition of the biomass main constituents

$$\Delta m_{biomass} = \Delta m_{cellulose} \cdot \%_{cellulose} + \Delta m_{lignin} \cdot \%_{lignin} + \Delta m_{hemicellulose} \cdot \%_{hemicellulose}$$

- First step: **Experiments** in TGA-FTIR and lab-scale device
  1. To check additive law
  2. To close mass balance with released gas and condensables
  3. To study the gas and condensables formation

TGA facility

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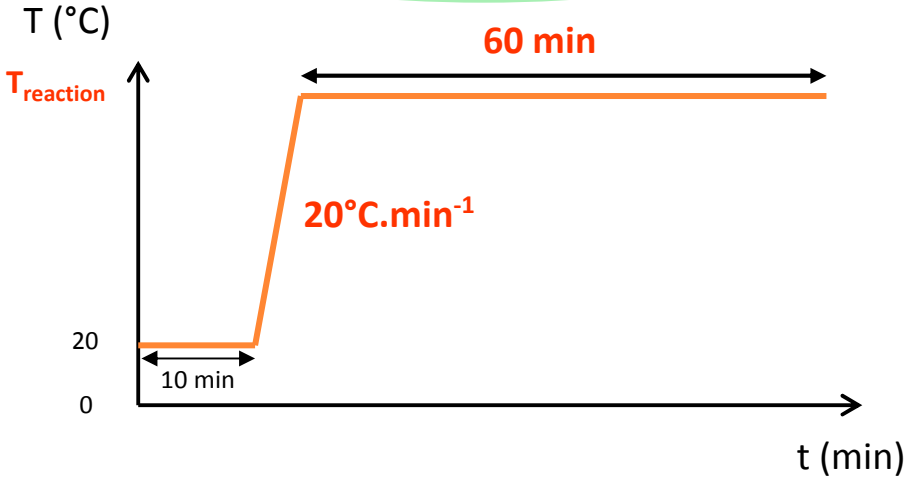
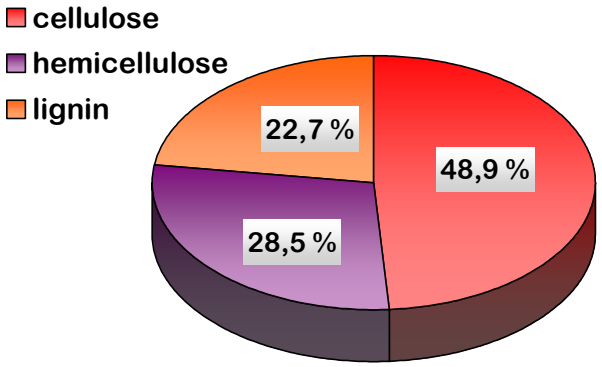
TGA (Setaram 92) — (230°C) — Gas analyzer : FTIR (Perkin-Elmer System 2000)

Atmosphere	N_2
Gas flowrate	30 mL.min^{-1}
Pressure	atmospheric
Temperature	250;280;300 °C



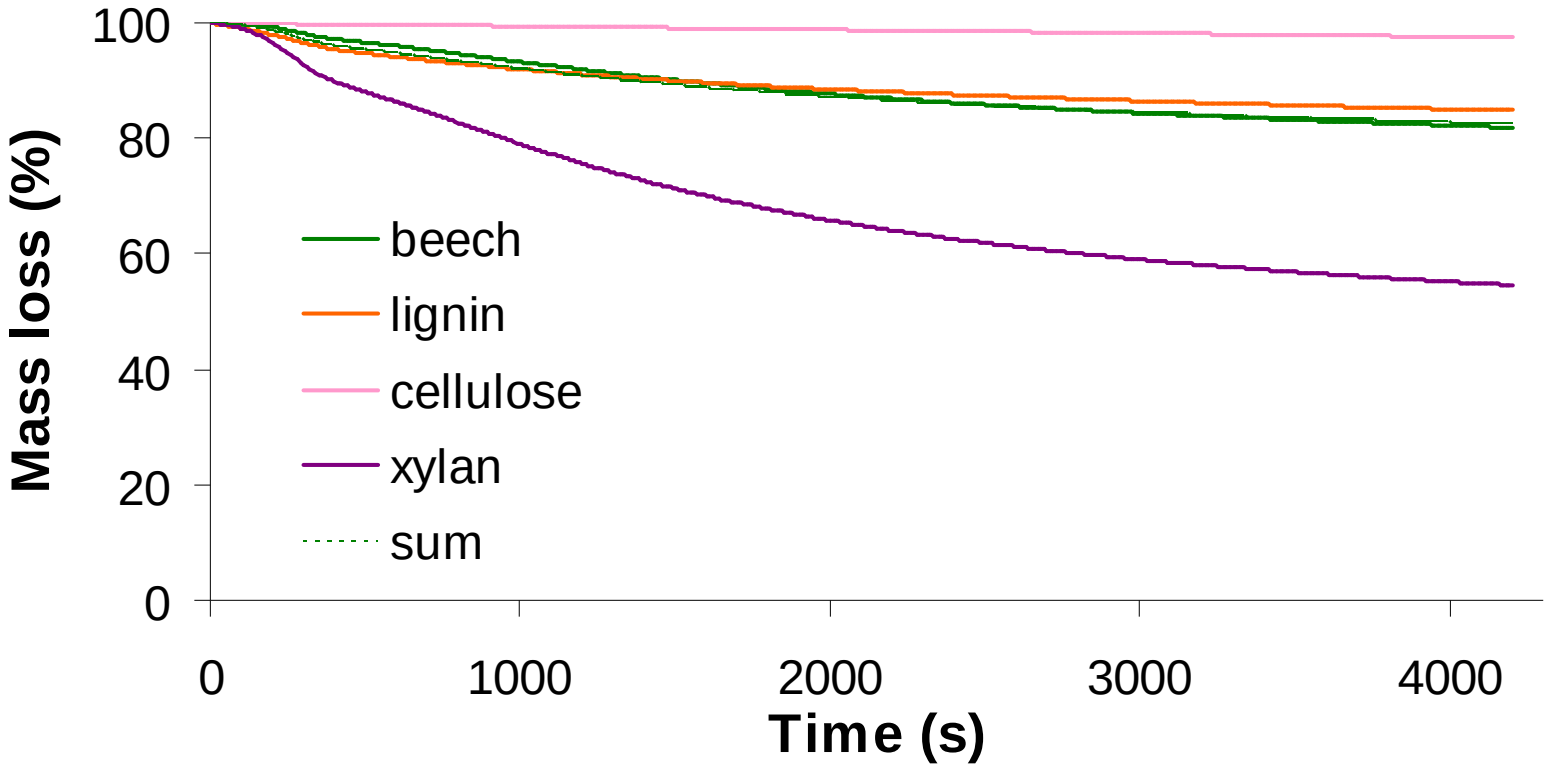


- **Beech**
- **Lignin (extracted from beech)**
- **Cellulose**
- **Xylan (85% hemicellulose)**

Study in chemical regime

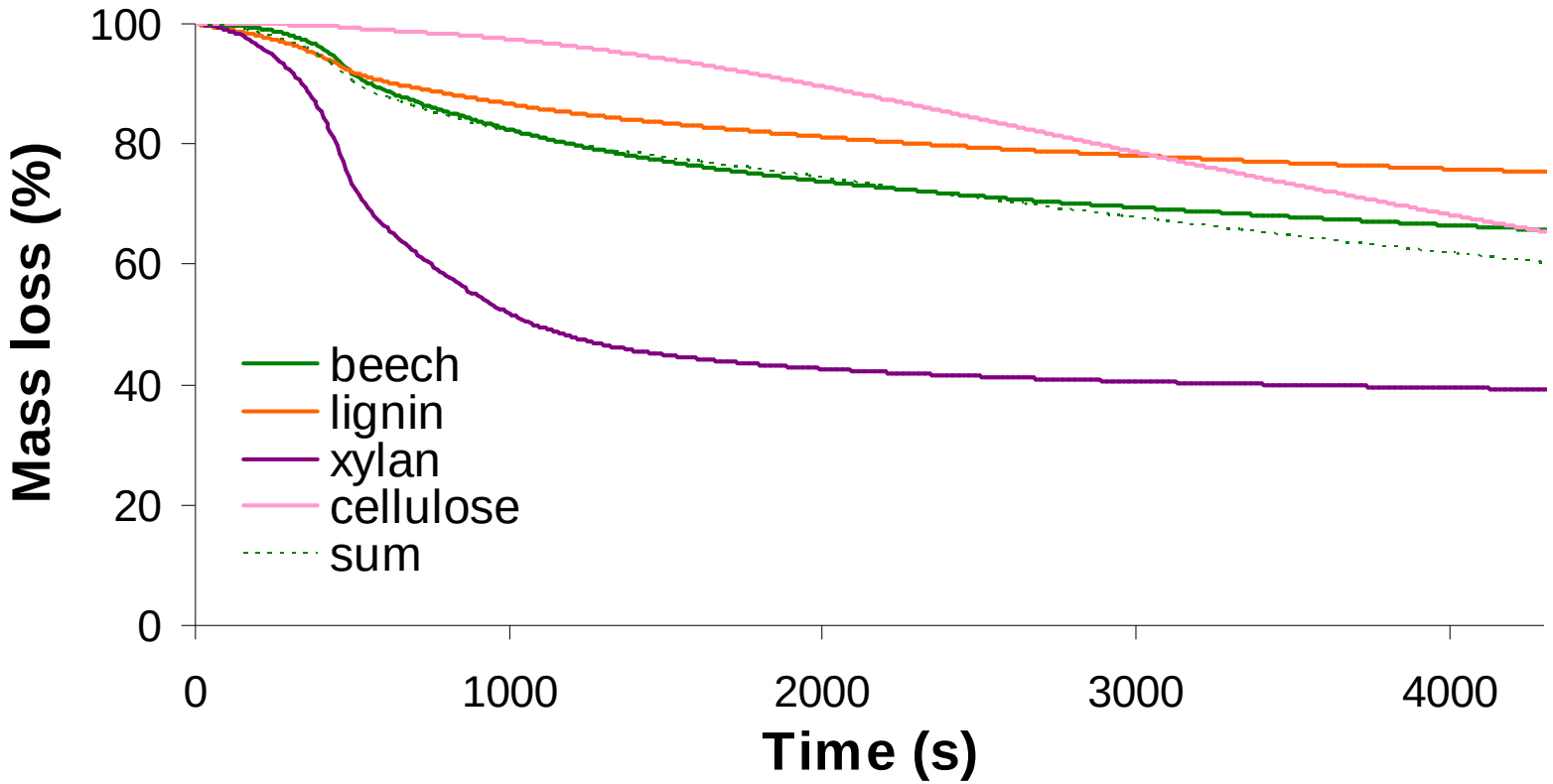
Error between replicates<1%

Results at 250°C



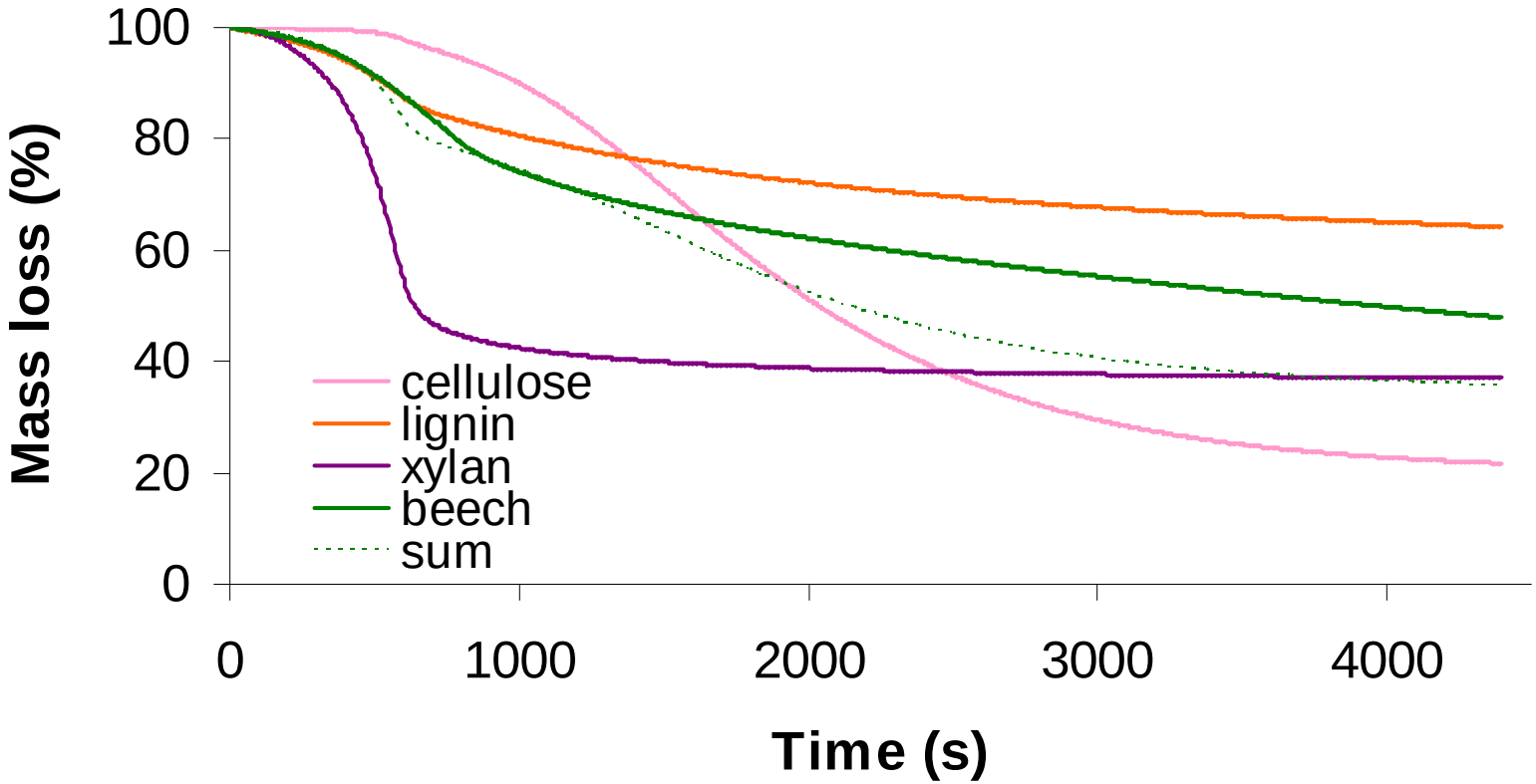
- Lignin: smooth and continuous mass loss
- Xylan: significant mass loss
- Cellulose: nearly no mass loss
- Additive law: OK

Results at 280°C



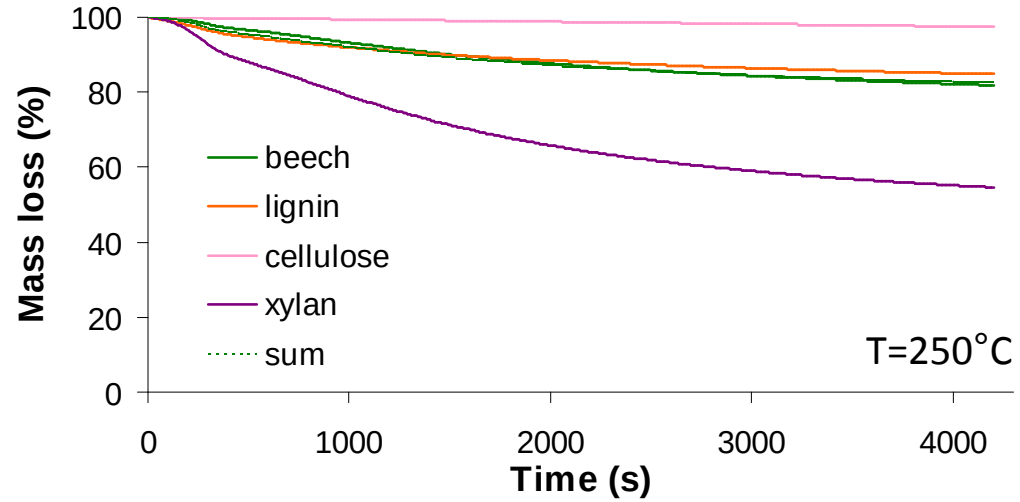
- Lignin: smooth and continuous mass loss
- Xylan: fast and sharp mass loss
- Cellulose: slow but significant mass loss
- Additive law: OK except for long duration (>2500 s)

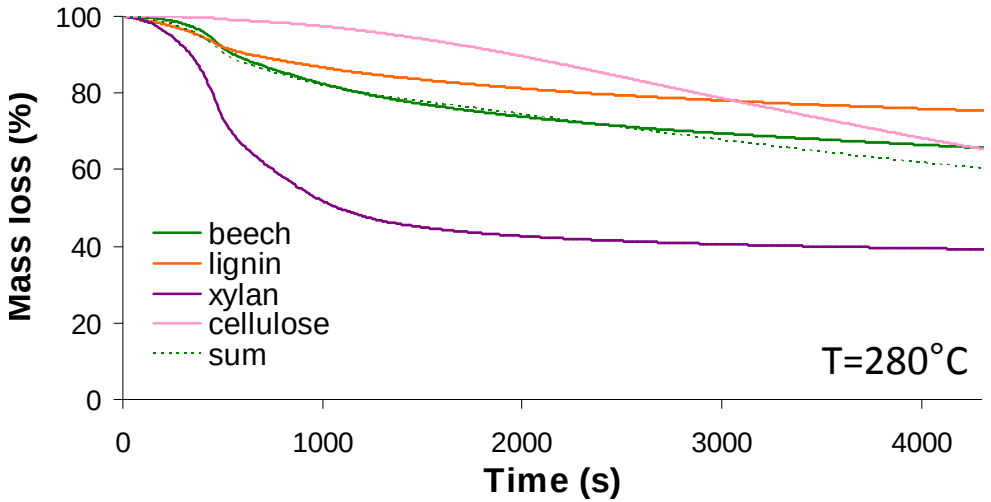
Results at 300°C

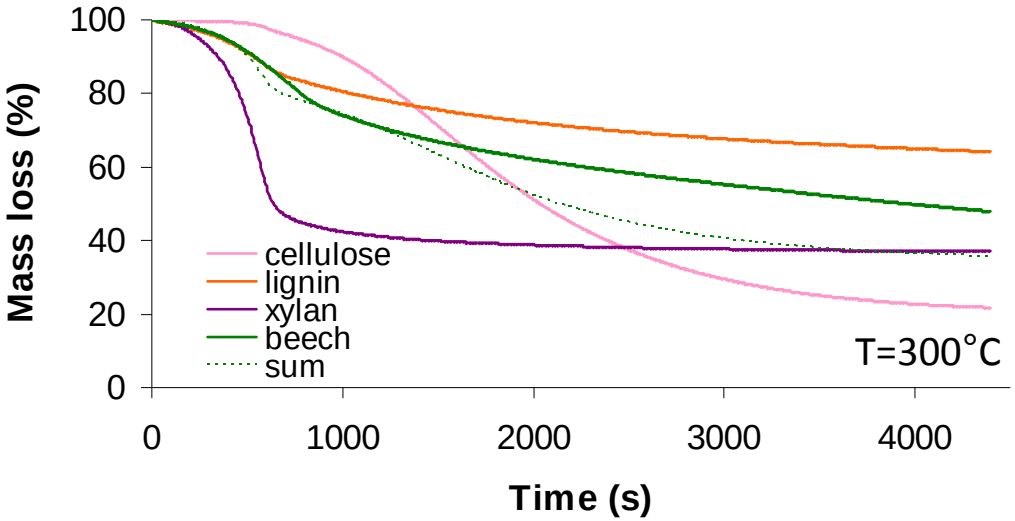


- Lignin: smooth and continuous mass loss
- Xylan: fast and very sharp mass loss
- Cellulose: slow but the highest mass loss after long duration
- Additive law: not valid

Synthesis of the results







Additive law:

- Valid at 250°C and 280°C for typical process duration
- Not valid at 300°C

↳ Slower decomposition of cellulose in beech

Long duration test at 300°C

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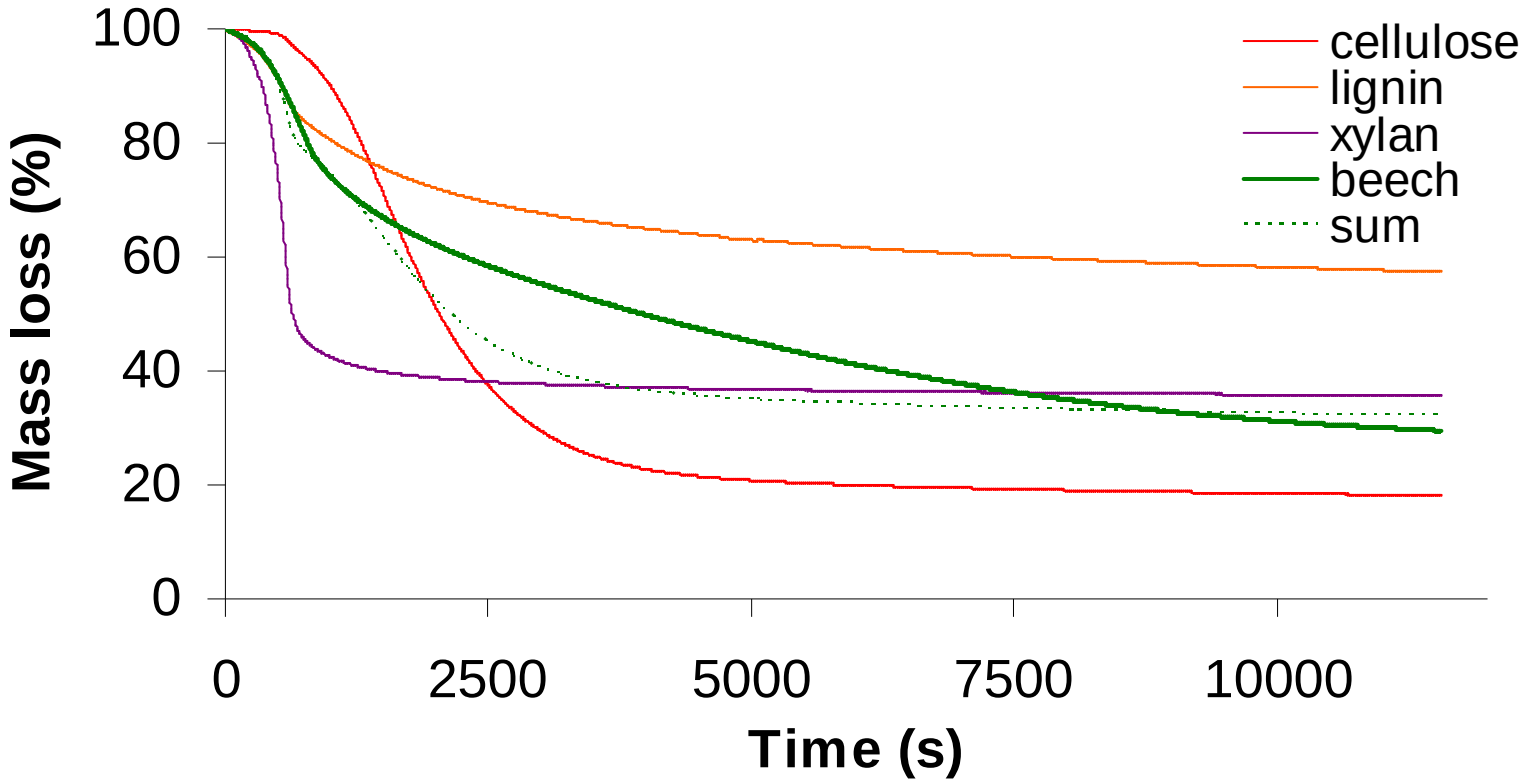

- OK for prediction of "final" solid yield
- Confirmation: gap due to slower decomposition of cellulose in beech
  - Interaction between constituents?
  - Structure of cellulose?

The lab-scale device ALIGATOR

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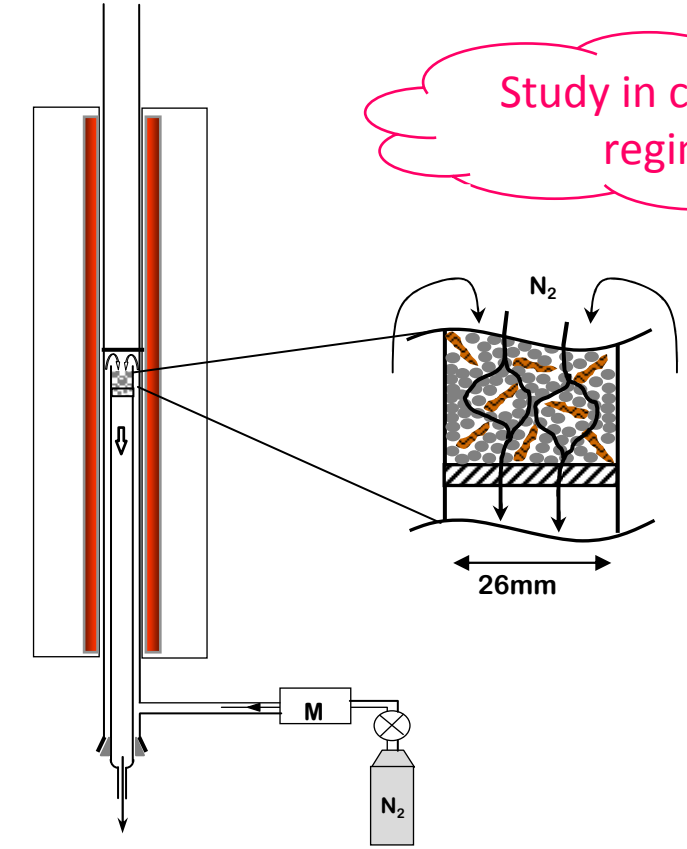
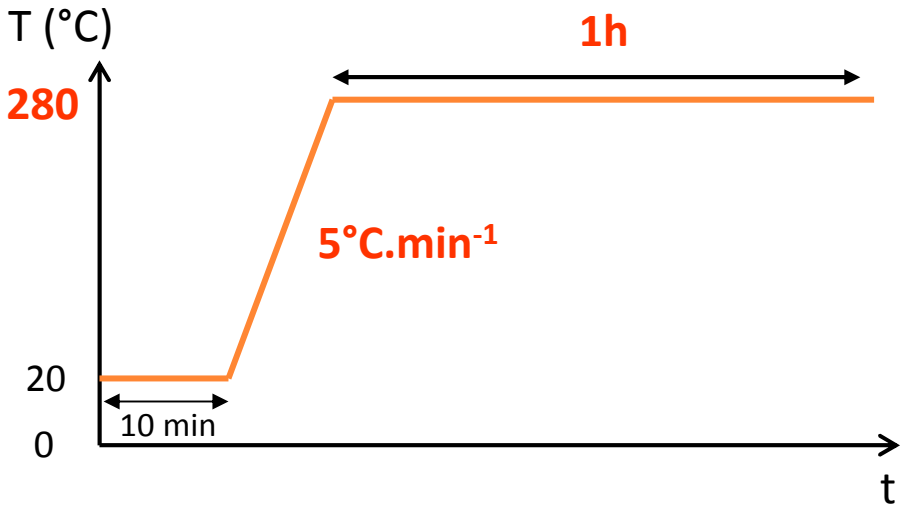


Study in chemical regime

Atmosphere	N_2
Gas flowrate	30 mL.min^{-1}
Pressure	atmospheric
Temperature	280°C
Biomass	beech
Sample mass	1.5 g



Global mass balance

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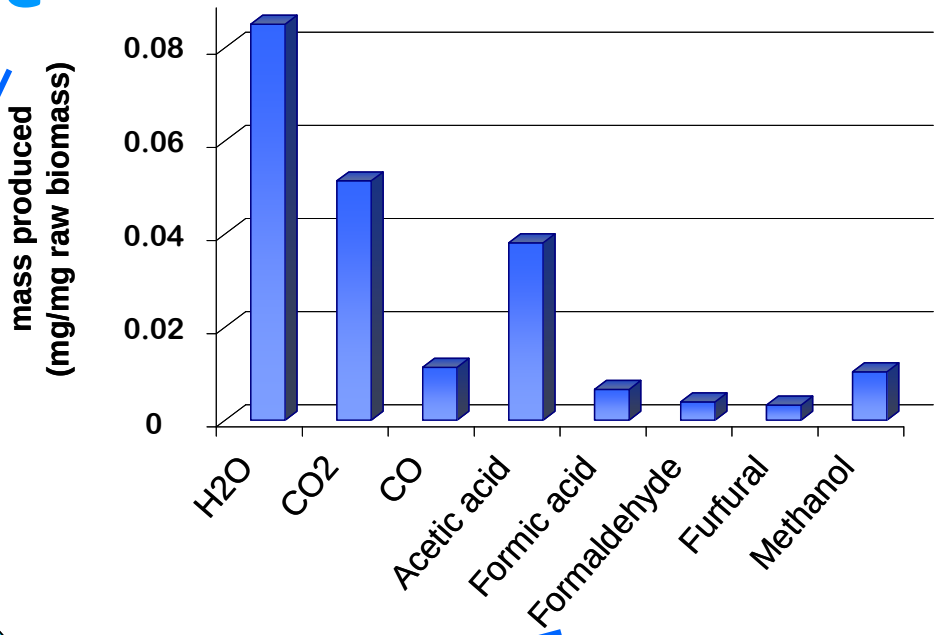
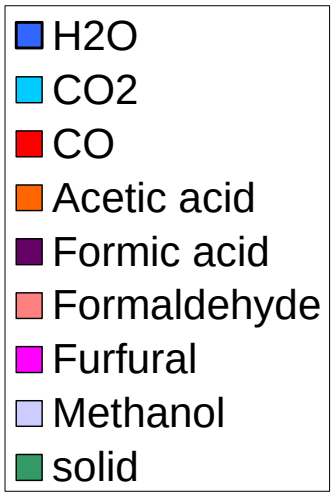
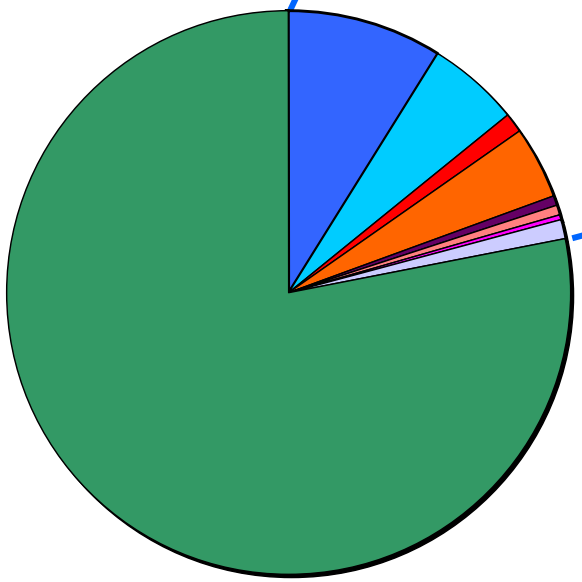
Torrefaction of beech
(280°C, 1h)







- Main products: H_2O, CO_2, acetic acid
- Significant yields of other species

TGA-FTIR device

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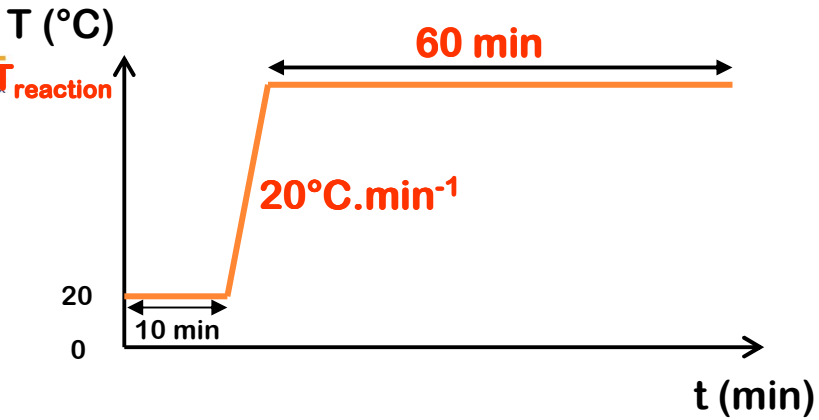

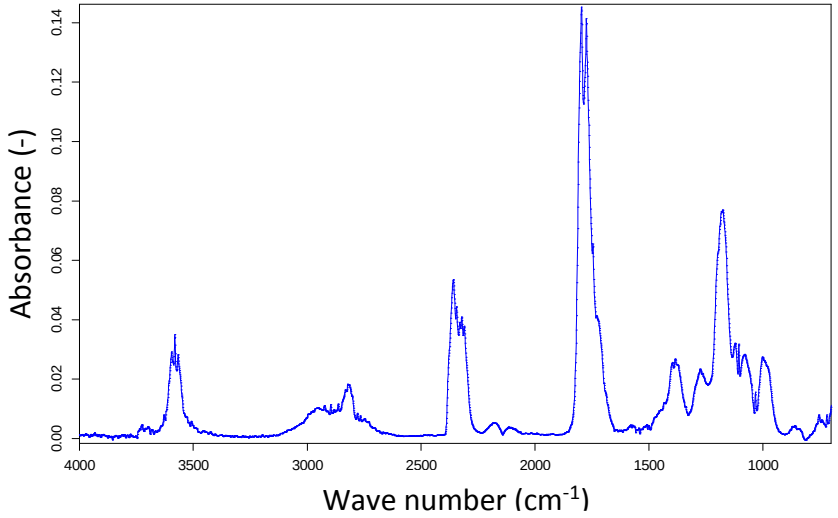

FTIR Spectrum
Torrefaction of beech (300°C, 900s)

- **Beech**
- **Lignin (extracted from beech)**
- **Cellulose**

Beech: Gas species mean value vs temperature

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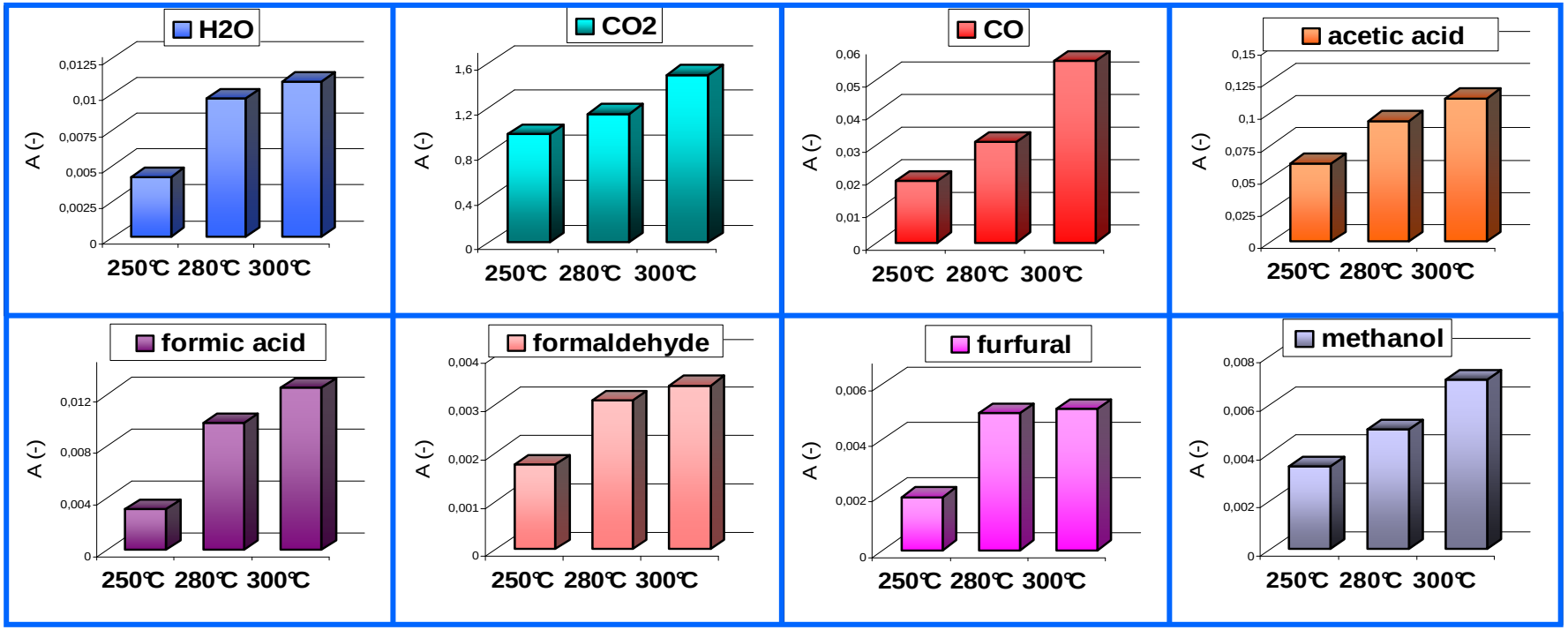
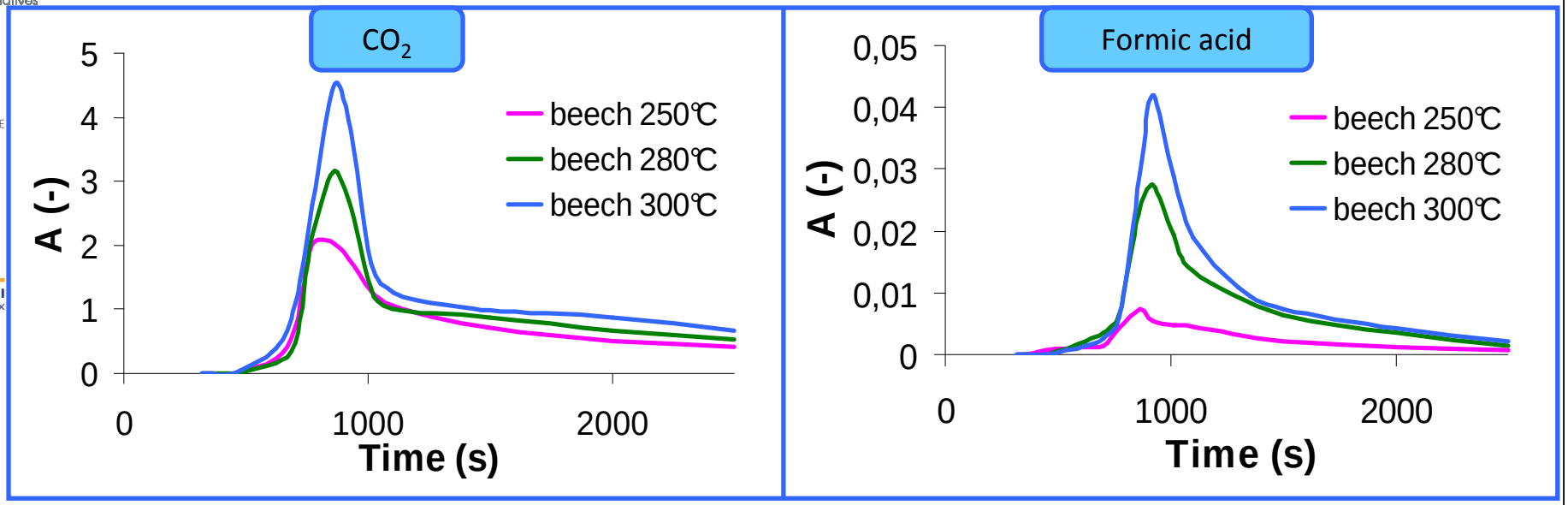


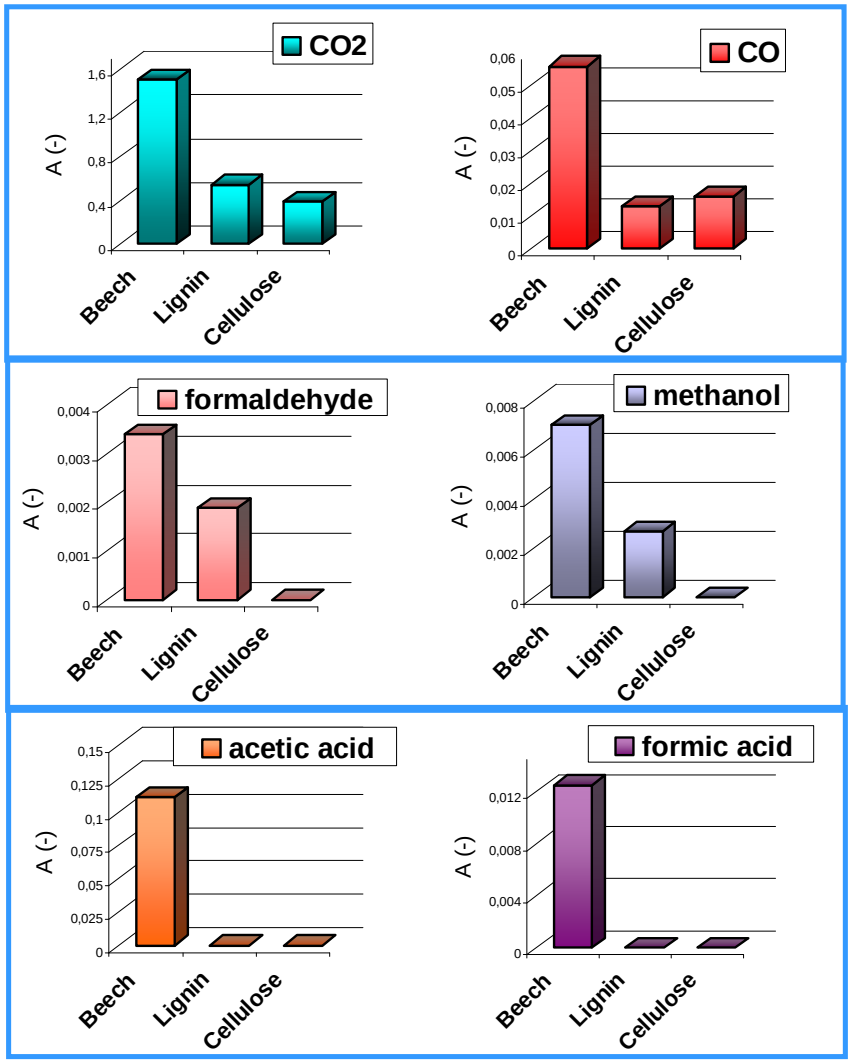
Increase of temperature ➡ Increase of each gas yield

Beech: CO_2 and formic acid vs time



- Increase of temperature ➡ Increase of each gas yield
- For both products: peak of concentration at the same time for all temperatures
- Long duration time:
  - CO_2 still released
  - No more formation of formic acid

Beech, lignin and cellulose: comparison at 300°C



CO_2 and CO produced both by lignin and cellulose

Formaldehyde and methanol not produced by cellulose

Acetic and formic acids neither produced by lignin nor cellulose

↳ Produced by hemicellulose

Conclusion and outlook

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	Solid mass loss	Gas and condensables formation
Process	Predicted by additive law (T=250°C; T=280°C,t<40 min)	•Main products for beech: H_2O, CO_2, acetic acid •Yields increase with T
Fundamental	Slower torrefaction of cellulose in wood than alone	•Similar peaks of formation •Not produced by all constituents •Acetic and formic acids produced by hemicellulose

What's next?

1. TGA-FTIR experiments on hemicellulose
2. Calibration of TGA-FTIR for quantification
3. Model development

If you have any questions or want more details, please contact:

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